COMPRESSED AIR

A MONTHLY MAGAZINE DEVOTED TO THE USEFUL APPLICATIONS OF COMPRESSED AIR

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COMPRESSED AIR

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A monthly magazine devoted to the useful applications of compressed air.

APRIL, 1907.

CONTENTS.

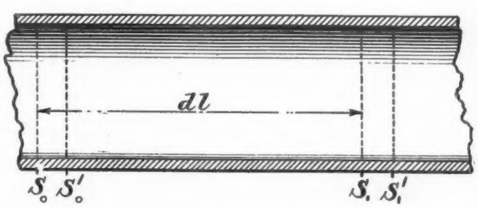
THE FLOW OF AIR IN LONG TUBES WITH SPECIAL REFERENCE TO PNEUMATIC DISPATCH.

By B. C. Batcheller.

PART I.

If a difference of pressure exists in different parts of a tube, a fluid filling the tube will flow from the place of higher pressure towards that of lower pressure. If the fluid be elastic—air, for example—as it moves it will expand according to well-known laws. The expansion indicates that work is being done. This work is expended in overcoming the resistance to flow, due to viscosity of the fluid and friction against the walls of the tube, resulting in eddy currents which, as they subside, impart heat to the gas, making the expansion nearly isothermal. The temperature of the air is determined by, and is nearly the same as that of the tube and its environment; if the air is at a different temperature when it enters the tube it becomes nearly the same after flowing a short distance, giving up or receiving heat by conduction, which transfer is accelerated by the rapid motion of the air particles among themselves. This has been demonstrated by the observations of M. Stockalper at St. Gothard's tunnel, and by observations on the postal tubes in Philadelphia. M. Stockalper observed that the temperature of the air flowing in a pipe 6,000 meters long was at every point about 3 degrees C. below that of the air surrounding the pipe.

FIG. 1.



William Cawthorne Unwin, formerly professor of engineering at the Guilds Central Technical College, London, was the first to construct a rational formula expressing the law of the flow of gases in long tubes. He assumed that the well-known formula for the flow of water, which has been tested by many careful experiments, is equally applicable to the flow of gases when modified so that the density and expansion of the elastic fluid as it flows is taken into consideration. Others have suggested using the formula for flow of water with a coefficient suited to the density of air but they have neglected to consider the constant change of density. Prof. Unwin's formula is derived by equating the work of expansion to the work of friction and the change of kinetic energy.

Derivation of the Fundamental Equation.

Figure 1 represents a short section of tube through which a constant current of air is flowing. The length of the tube between the transverse sections S_0 and S_1 is dl, the diameter d and the area of cross section A. Let P and u be the pressure and velocity at S_0, $P + dP$ and $u + du$ the same quantities as S_1. If in a short time, dt, the mass S_0S_1 moves to the position $S_0{}^1S_1{}^1$ then the distance $S_0S_0{}^1 = udt$ and $S_1S_1{}^1 = (u + du)dt$

The work of expansion of $A\ u\ d\ t$ cubic feet of air to $A\ (u + du)\ dt$ cubic feet, at a pressure initially P, is

(1)

$$A\ P\ du\ dt$$

Let T = the absolute temperature.
G = the density or weight of air in pounds per cubic foot.
V = the volume of air in cubic feet per pound.
W = the weight of air in pounds flowing per second.

By the combined laws of Mariotte and Gay Lussac.

(2)

$$\frac{PV}{T} = R \text{ constant.}$$

Assuming the tube to have a uniform section, since the rate of flow is constant, the same weight of air flows past every transverse section per second therefore:

$$W = AGu \text{ constant,}$$

Or

(3)

$$W = \frac{Au}{V}$$

Combining this with (2)

(4)

$$u = \frac{WRT}{AP}$$

$$du = -\frac{WRT}{AP^2}\,dP$$

substituting in (1), the work of expansion is

(5)

$$-\frac{WRT}{P}\,dP\,dt$$

By analogy with the flow of liquids the head lost in friction measured in feet of fluid is

$$f\,\frac{u^2}{2g}\,\frac{dl}{m}$$

$$\text{Let}\quad H = \frac{u^2}{2g}$$

then the loss of head is

$$f\,H\,\frac{dl}{m}$$

Since Wdt is the weight of air flowing through the space in the time dt, the work expended in friction is

(6)

$$f\,\frac{H}{m}\,W\,dl\,dt$$

The change of kinetic energy in the time dt is the difference of the kinetic energy of $S_1S_1{}^1$ and $S_0S_0{}^1$, that is

(7)

$$\frac{W}{2g}\,dt\left\{(u + du)^2 - u^2\right\}$$

$$= \frac{W}{g}\,u\,du\,dt$$

$$= W\,dH\,dt$$

The work done by gravity is zero if the tube is horizontal and this condition can be assumed usually without much error.

The work of the pressures on the sections S_0S_1 is

$$PA\,udt - (P + dP)\,A\,(u + du)\,dt$$

But since the temperature is constant

$$Pu = \text{constant}$$

$Pdu + udP = 0$, and the work of pressure is zero.

Placing the work of expansion equal to the work of friction and change of kinetic energy

(8)

$$-\frac{WRT}{P}\,dP\,dt = f\,\frac{H}{m}\,W\,dl\,dt + W\,dH\,dt$$

$$-\frac{RT}{P}\,dP = f\,\frac{H}{m}\,dl + dH$$

(9)

$$-\frac{RT}{HP}\,dP = f\,\frac{dl}{m} + \frac{dH}{H}$$

$$u = \frac{WRT}{AP}$$

$$H = \frac{u^2}{2g} = \frac{W^2R^2T^2}{A^2P^2 2g}$$

Substituting this value of H in (9)

(10)

$$-\frac{2g\,A^2\,P}{W^2\,R\,T}\,dP = f\,\frac{dl}{m} + \frac{dH}{H}$$

Integrating

$$-\frac{g\,A^2\,P^2}{W^2\,R\,T} = f\,\frac{1}{m} + \log H + \text{Constant}$$

Substituting the limits:

$$P = P_1 \qquad l = o \qquad H = H_1$$
$$P = P_2 \qquad l = L \qquad H = H_2$$

$$-\frac{g\,A^2}{W^2RT}\left(P_2^2 - P_1^2\right) = f\,\frac{L}{m} + \log\frac{H_2}{H_1}$$

Remembering that P_1 is greater than P_2 and substituting for W and H

$$W^2 = \frac{A^2\,P_1^2\,u_1^2}{R^2\,T^2}$$

$$\frac{gRT}{P_1^2\,u_1^2}\left(P_1^2 = P_2^2\right) = f\,\frac{L}{m} + \log\frac{P_1}{P_2}$$

Solving for u_1

Let p_1 and p_2 be pressures in pounds per square inch, R = 53.15 and r = the temperature of the air in degrees Fahrenheit, then

(13)

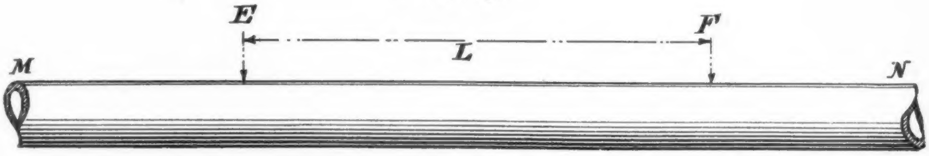
$$u = \sqrt{427.86\,\frac{(461 + r)\,d}{f\,L}\,\frac{p_1^2 - p_2^2}{p_1^2}}$$

Let MN, Fig. 2, represent a long tube of diameter d, in which a steady current of air is flowing from M toward N. Let the air pressure be measured with a pressure-gauge at two points E and F distant L feet apart. If the absolute pressure at E be p_1 and at F p_2, then the velocity of the air at E may be found by substituting these values in the above formula (13).

Pressure at Any Distance from the Origin

If the initial velocity and pressure, u_1 and p_1 are known, then the pressure p at any distance L from the origin can be computed thus:

FIG. 2.



(11)

$$u_1 = \sqrt{\frac{\dfrac{g\,R\,T\,(P_1^2 - P_1^2)}{P_2^2}}{P_1^2\left(f\,\dfrac{L}{m} + \text{Log}\,\dfrac{P_1}{P_2}\right)}}$$

When L is great $\log\frac{P_1}{P_2}$ is so small compared with $f\,\frac{L}{m}$ that it may be neglected; then

(12)

$$u_1 = \sqrt{\frac{g\,R\,T\,m\,(P_1^2 - P_2^2)}{f\,L\quad P_1^2}}$$

This is the fundamental equation for the flow of air in a long tube.

For tubes of circular section and diameter d, expressed in feet

$$m = \frac{d}{4}$$

(14)

$$p_x = p_1\sqrt{1 - \frac{f\,u_1^2\,L_x}{427.86\,(461 + t)\,d}}$$

Time of Transit.

Putting t for the time of transit of a particle of air from E to F, Fig. 2,

$$t = \int_o^L \frac{dl}{u}$$

From (10) neglecting $\dfrac{dH}{H}$

$$f\,\frac{dl}{m} = -\frac{2g\,A^2\,P}{W^2\,R\,T}\,dP$$

$$dl = -\frac{2g\,A^2\,P}{f\,W^2\,R\,T}\,dP$$

From (4) $\quad u = \dfrac{W\,R\,T}{A\,P}$

Therefore:

$$t = \int_{P_1}^{P_2} -\frac{2gm\,A^3\,P^2}{f\,W^3\,R^2\,T^2}\,dP$$

Integrating between the limits of P_1 and P_2.

$$t = \frac{2g\,m\,A^3}{3\,f\,W^3\,R^2\,T^2}\left(P_1^3 - P_2^3\right)$$

From (4) $$W = \frac{A\,P_1\,u_1}{R\,T}$$

Substituting

$$t = \frac{2gm\,R\,T}{3\,f\,u_1^3}\;\frac{P_1^3 - P_2^3}{P_1^3}$$

Substituting for u_1 the value given in (12)

(15)

$$t = \frac{2}{3}\,\frac{f^{1/2}\,L^{3/2}}{(g\,m\,R\,T)^{1/2}}\;\frac{P_1^3 - P_2^3}{(P_1^2 - P_2^2)^{3/2}}$$

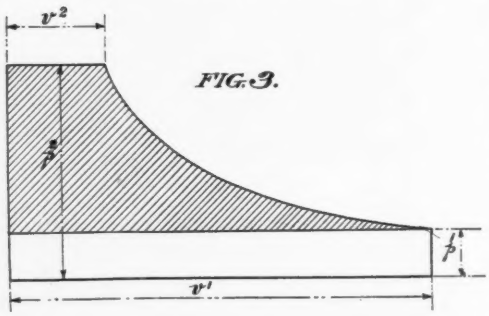


FIG. 3.

For circular tubes of diameter d, pressures p_1 and p_2 in pounds per square inch and temperature r in degrees Fahrenheit

(16)

$$t = 0.03223\sqrt{\frac{f\,L^3\,(p_1^3 - p_2^3)^2}{d\,(461 + r)\,p_1^2 - p_2^2)^3}}$$

Which gives the time of transit in terms of the initial and terminal pressures, temperature and dimensions of the tube.

Mean Velocity.

Having computed the time of transit, the mean velocity can be determined by dividing the length of tube L, by the time t

(17)

$$u_{\text{mean}} = \frac{L}{t}$$

or by substituting the value of t as given in (16) u_m can be computed directly from the pressures and dimensions of the tube, thus:

(18)

$$u_m = 31.027\sqrt{\frac{d\,(461 + r)\,(p_1^2 - p_2^2)^3}{f\,L\;\;(p_1^3 - p_2^3)^2}}$$

It is interesting to note what the limiting velocity will be as the terminal pressure p_2 approaches zero. According to (18) when $p_2 = 0$

$$u^1_m = 31.027\sqrt{\frac{d\,(461 + r)}{f\,L}}$$

which is independent of the initial pressure. All that need be said is that this is an application of the formula beyond the realm of experiment, and is only interesting as a speculation.

Velocity at Any Distance from the Origin.

Having obtained the initial velocity of the air in the tube, the velocity at other points can be computed. For isothermal expansion and a constant cross section of the tube

$$u_2\,p_2 = u_1\,p_1$$

when u_2 and p_2 are the velocity and pressure at any desired distance from the origin and $u_1\,p_1$ the initial velocity and pressure.

(19)

Therefore: $$u_2 = u_1\,\frac{p_1}{p_2}$$

or by substituting (14)

(20)

$$u_2 = \sqrt{\frac{427.86\,(461 + r)\,d\,u_1^2}{427.86\,(461 + r)\,d - f\,u_1\,L}}$$

Weight of Air Flowing Per Second.

From (4) the weight of air flowing per second is

$$W = \frac{APu}{RT}$$

If u_1 be the initial velocity and p_1 the initial pressure, this becomes

(21)

$$W = \frac{A\,p_1\,u_1}{RT}$$

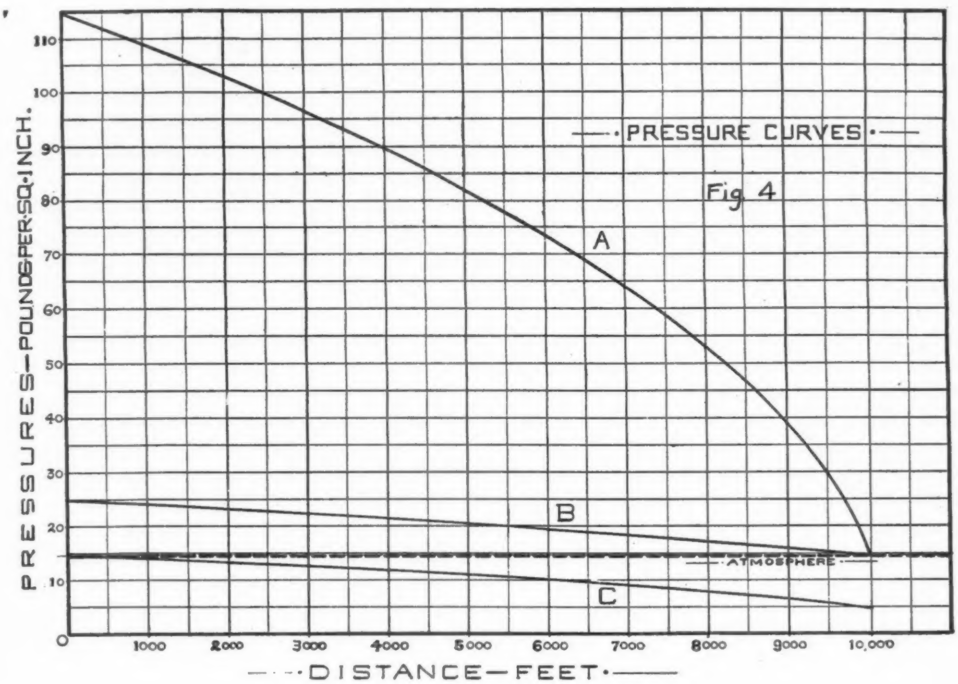
(22)

or $$W = 0.01478\,\frac{d^2\,p_1\,u_1}{461 + r}$$

(23)

$$W = \sqrt{\frac{A^2 g\, d}{4\, \mathbf{f}\, RL\, (461+r)} (P_1^2 - P_2^2)}$$

Substituting for u_1 the value given in (12)



(24)

$$W = 0.30566 \sqrt{\frac{d^5}{\mathbf{f}\, L\, (461 + r)} (p_1^2 - p_2^2)}$$

The quantity of air flowing through a tube expressed in cubic feet per unit of time, at atmospheric pressure, is easily computed when the velocity at the open end of the tube is known.

A discussion of the coefficient **f** is deferred to Part II.

POWER.

From the foregoing formulæ an expression might be derived for the power consumed to maintain a constant flow of air, but in practice the source of power is usually some form of air compressor, and since there is more or less loss of work in the form of heat between the compressors and the tube, the power can best be computed at the air-compressing cylinder.

In the tube the air expands isothermally, but in the cylinder of most air-compressors used for the operation of pneumatic dispatch tubes, the compression is nearly adiabatic, since the pressure seldom rises above 15 lbs. per square inch, so that water jackets are not required and but little heat escapes through the walls of the cylinder. Between the compressor and the tube, or immediately after entering the tube, most of the heat of compression is lost.

Let v_2 = the initial volume of air compressed per minute.

v_1 = the volume of the same air after compression.

p_2 = the initial pressure.

p_1 = the final pressure.

Referring to Fig. 3, the relation of volume and pressure for adiabatic changes is expressed bv the formula

(25)

$$\frac{v}{v_2} = \left(\frac{p_2}{p} \right)^{\frac{1}{k}}$$

The general expression for E, the work done

when the volume and pressure of a gas changes, is

$$E = \int_{p_2}^{p_1} v \, d\, p$$

Substituting for v its value in (25)

$$E = v_2 p_2^{\frac{1}{k}} \int_{p_2}^{p_1} p^{-\frac{1}{k}} \, d\, p$$

$$E = \frac{1}{1-\frac{1}{k}} v_2 p_2^{\frac{1}{k}} \left[p_1^{1-\frac{1}{k}} - p_2^{1-\frac{1}{k}} \right]$$

$$E = \frac{k}{k-1} v_2 p_2 \left[\left(\frac{p_1}{p_2} \right)^{\frac{k-1}{k}} - 1 \right]$$

For air, $K = 1.41$

Therefore:

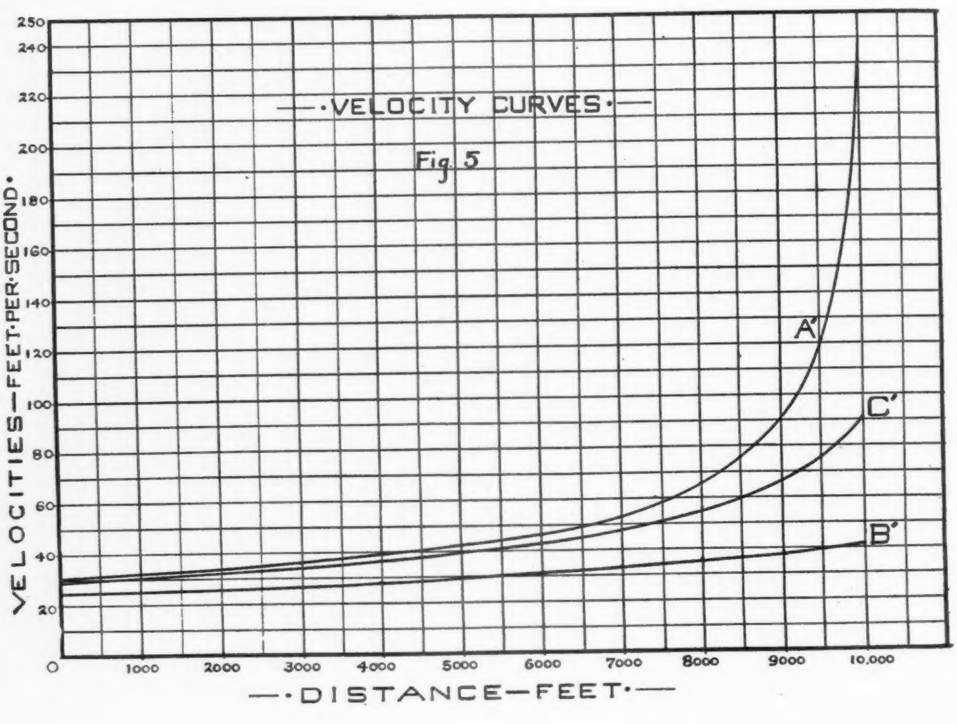
$$E = 3.44\, v_2\, p_2 \left[\left(\frac{p_1}{p_2} \right)^{.29} - 1 \right]$$

This is the work represented by the shaded portion of figure, which may be considered an ideal indicator card of an air compressor.

Since one horse power is the expenditure of 33,000 foot-pounds per minute, the power necessary to do this amount of work in one minute is

$$H.P. = \frac{3.44}{33000} v_2\, p_2 \left[\left(\frac{p_1}{p_2} \right)^{.29} - 1 \right] \quad (26)$$

When v_2 is expressed in cubic feet p_1 and p_2 must be pounds per square foot.

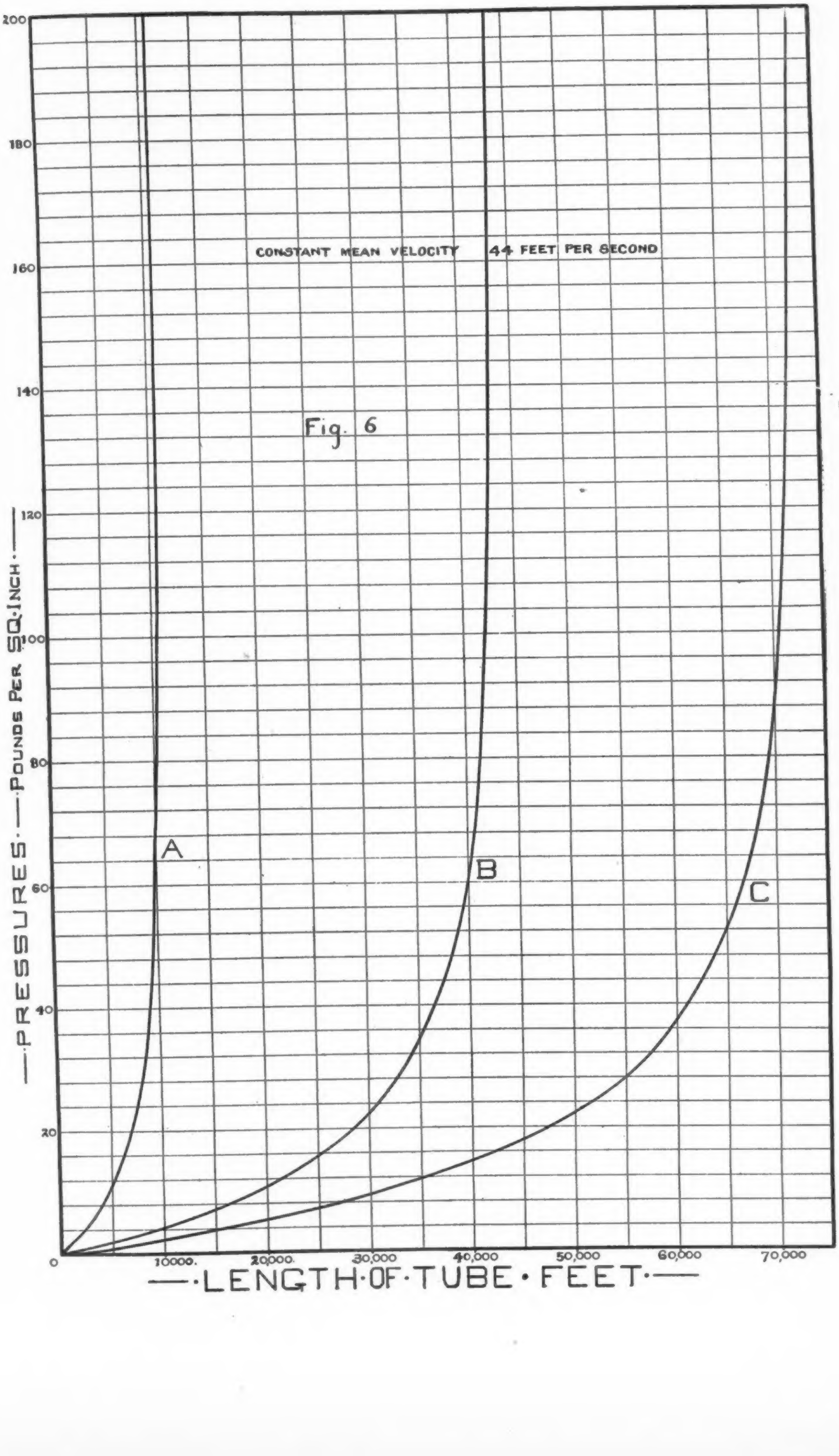


Examples.

A few examples have been selected to illustrate the laws of the flow of air in long tubes, as expressed by the foregoing formulæ.

Pressure and Velocity Curves.

Imagine a tube ten thousand feet long, and suppose that a constant pressure of one hundred pounds per square inch be maintained at the initial end, and that the air be allowed to flow freely through the tube into the atmosphere at the far end. The flow will be constant and the temperature of the air in the tube is assumed to be constant. The following table


CONSTANT MEAN VELOCITY 44 FEET PER SECOND
Fig. 6
A
B
C
200
180
160
140
120
100
80
60
40
20
0
10000.
20,000.
30,000
40,000
50,000
60,000
70,000
·PRESSURES· ·POUNDS PER SQ·INCH·
·LENGTH·OF·TUBE·FEET·

gives the pressure and velocity of the air in the tube at each thousand feet along the tube:

100 pounds pressure.

Distance from Initial End. Feet.	Absolute Air Pressure. lbs. per sq. in.	Velocity of the Air. Feet per second.
0	114.7	30.38
1000	108.92	31.99
2000	102.80	33.89
3000	96.30	36.18
4000	89.33	39.00
5000	81.77	42.61
6000	73.42	47.46
7000	64.02	54.43
8000	52.95	65.80
9000	38.86	89.66
9500	29.38	118.60
10000	14.70	237.02

These pressures and velocities have been plotted (Figs. 4 and 5) and the curves A and A^1 drawn. The most striking characteristic of the pressure curve is its convexity upward being in fact an arc of a parabola. The pressure falls more and more rapidly as the open end of the tube is approached. The pressure curve of an inelastic fluid, like water, is a straight line.

The velocity curve A^1, Fig. 5, is more striking than the pressure curve. The initial velocity is about 30 feet per second. As the air flows along the tube the velocity increases gradually at first, then faster and faster until the open end is approached, where it rises to the maximum of 237 ft. per second. This example is an extreme case, purposely selected to show the variation in pressure and velocity. In practice a pressure as high as 100 lbs. per square inch would be impracticable.

For another example, assume a constant initial pressure of 10 lbs. per square inch, at the end of a tube 10,000 ft. long, the far end being open to the atmsophere. The following table gives the pressures and velocities along the tube as in the first example:

10 pounds pressure.

Distance from Initial End. Feet.	Absolute Air Pressure. lbs. per sq. in	Velocity of the Air. Feet per second.
0	24.70	24.61
1000	23.89	25.45
2000	23.05	26.38
3000	22.18	27.41
4000	21.27	28.58
5000	20.32	29.91
6000	19.33	31.45
7000	18.28	33.25
8000	17.17	35.40
9000	15.98	38.04
9500	15.35	39.59
10000	14.70	41.36

The curves B and B^1 (Figs. 4 and 5) illustrate this example graphically. In this case the pressure curve is almost a straight line slightly convex upward, and the velocity curve more nearly horizontal than in the first example. It is interesting to note that, although the initial pressure in the first example is ten times greater than in the second, the initial velocity is only about 20 per cent. greater showing how little effect an increase of initial pressure has on the initial velocity; on the other hand, it produces great inequality in the velocity at different parts of the tube.

Another example will be interesting showing the pressures and velocities when the air is exhausted from the tube—that is to say, for pressures below the atmospheric.

Assume a pressure of —10 lbs., or 4.7 lbs. absolute at the far end of the tube, the near end being open to the atmosphere. Under these conditions the current in the tube is in the same direction as in the previous case, but the power must be applied at the far end. Let the length of the tube be the same as before viz., 10,000 feet.

10 pounds vacuum.

Distance from Initial End. Feet.	Absolute Air Pressure. lbs. per sq. in.	Velocity of the Air. Feet per second.
0	14.70	29.02
1000	14.02	30.42
2000	13.31	32.04
3000	12.57	33.95
4000	11.77	36.25
5000	10.91	39.36
6000	9.99	42.72
7000	8.96	47.61
8000	7.80	54.67
9000	6.44	66.23
9500	5.64	75.66
10000	4.70	90.77

The variations of pressure and velocity are shown graphically in curves C and C^1 (Figs. 4 and 5). Curve C has slightly more convexity than curve B, otherwise it is similar. The velocity curve C^1 is considerably higher than B^1, showing clearly that with the same difference in pressure, much higher velocities can be obtained by exhausting the air than by compressing it. In other words, it is more economical to maintain a given speed of flow by exhaustion than by compression.

In the examples just cited the curves of pressure are independent of the diameter of the tube and of the coefficient of friction.

In the practical operation of pneumatic tubes it is sometimes desirable to know the initial and final velocity of the air, but more frequently the mean velocity between two given points is the quantity that is wanted, for it determines the time of transit. The mean velocity is computed by formula (18).

In order to show what initial pressures will be required to give a mean velocity of thirty miles per hour (44 ft. per second) in tubes of coefficient f vary with the diameter of the tube,

various sizes and lengths, the following table has been computed and the results plotted in Fig. 6. Tubes having a diameter of 3, 8 and 12 inches have been selected to cover a wide range of sizes.

A constant air current is assumed with the far end of the tube open to the atmosphere.

Curves A, B and C are for 3, 8 and 12 inch tubes respectively.

3-ince Tube.		8-inch Tube.		12-inch Tube.	
Initial Gauge Pressure. Lbs. per sq. in.	Length of Tube. Feet.	Initial Gauge Pressure. Lbs. per sb. in.	Length of Tube. Feet.	Initial Gauge Pressure. Lbs. per sq. in.	Length of Tube Feet.
1.60	1000	0.38	1000	0.23	1000
1.41	2000	1.17	3000	0.69	3000
5.49	3000	2.01	5000	1.17	5000
7.95	4000	3.37	8000	1.92	8000
10.92	5000	4.35	10000	2.44	10000
14.68	6000	5.42	12000	2.98	12000
19.70	7000	7.18	15000	3 83	15000
26.96	8000	10.50	19707	10.50	32971
39.16	9000	23.	30377	23.	50824
67.56	10000	50.	38507	50.	64424
100.00	10412	100.	42127	100.	70482
200.00	10752	200.	43501	200.	72780

Limiting Lengths.

It will be noticed that the pressures increase much more rapidly than the lengths, especially towards the bottom of the table; and that the lengths are approaching a limit that can not be exceeded, no matter how great the initial pressure may be. In other words, for every diameter of tube and mean velocity there is a length that can not be exceded even though the pressure be infinite.

Transforming formula (18).

$$L = \frac{(31.027)^2\ Td}{f u_m^2}\ \frac{(p_1^2 - p_2^2)^3}{(p_1^3 - p_2^3)^2}$$

$$L = \frac{(31.027)^2\ Td}{f\ u^2}\ \frac{(p_1{}^2\ p_2{}^2)^3}{(p_1{}^3\ p_2{}^3)^2}$$

Let $p_1 =$ infinity; then

$$L_{Limit} = \frac{31.027Td}{f\ u_m^2}$$

(31)

which is the limiting length of tube, of diameter d through which air at temperature T can ce made to flow with a mean velocity u_m. It is the asymtote of the pressure curves of Fig. 6 which are drawn by plotting the pressures and lengths of the foregoing table.

The following table contains the limiting lengths of tubes from 1 to 144 inches diameter through which air can be made to flow with a mean velocity of fifteen, thirty and sixty miles per hour (22, 44 and 88 feet per second) computed by formula (31). (Values of the coefficient f vary with the diameter of the tube and in computing this table values given by Ulwin's formula have been used. See Part II.)

Diameter of Tube. Inches.	Mean Velocity 22 ft. per sec. Limiting Length of Tube. Miles.	Mean Velocity 44 ft. per sec. Limiting Length of Tube. Miles.	Mean Velocity 88 ft. per sec. Limiting Length of Tube. Miles.
1	1.32	0.33	.08
2	4.32	1.08	.27
3	8.48	2.12	.53
4	12.76	3 19	.80
6	22.72	5.68	1.42
8	33.40	8.35	2.09
10	44.52	11.13	2.78
12	55.88	13.97	3.49
15	73 24	18.31	4.58
18	90.34	22.58	5.64
24	126.	31.59	7.90
36	198.	49.53	12.38
48	270.	67.58	16 89
72	416.	104.	26.
96	560.	140.	35.
120	704.	176.	44.
144	852.	213.	53.

By an examination of the curves (Fig. 6) it will be seen that these limiting values can not be even approached. In practice pressures seldom exceed 15 lbs. per square inch and that pressure will only give a speed of thirty miles per hour in 3-inch tubes, not more than one mile long, while the limiting length for that speed is 2.12 miles.

An inspection of formula (31) shows that the limiting length varies inversely as the square of the mean velocity; therefore, for a mean velocity of sixty miles per hour the lengths are one-quarter as great as for thirty miles per hour. On the other hand, for a mean velocity of fifteen miles the lengths are four times greater.

As stated elsewhere, these are applications of the formulæ beyond the limits of experiment and therefore must be used with caution.

We have no experiments from which to compute the coefficient of friction, for tubes more than 12 inches in diameter, but it is interesting and instructive to apply our formulæ to larger tubes, for they are frequently proposed as a means of passenger and freight transportation.

Several experimental tubes sufficiently large for passenger traffic have already been constructed, and a 4-foot tunnel, about two miles long was built under the streets of London for transportation of mail. The formula shows that the limiting length of a tube 10 feet in diameter for a mean velocity of sixty miles per hour, is forty-four miles, but to obtain this velocity in a tube only nineteen miles long would require an initial pressure of 10 lbs. per square inch, consuming 20,330 horse power in the compression of 567,360 cu. ft. of air per minute—all this to move the air through the tube, to say nothing of the additional power necessary to propel cars or trains. It is quite evident that this would not be a practical method of operating a railway at high speeds for long distances, however successful it might be for short distances.

(To be continued.)

SOME IMPORTANT ELEMENTS OF ECONOMY IN THE STRAIGHT LINE AND DUPLEX TYPES OF COMPOUND AIR COMPRESSORS.*

By Lucius I. Wightman.

(Concluded from March.)

REDUCED PRESSURES AND TEMPERATURES IN THE AIR CYLINDERS DUE TO COMPOUNDING

Inversely the same things are true of the resistances and temperatures in the air cylinders. The pressure is not carried as high in the low pressure cylinder, and since in the high pressure cylinder the pressure at the beginning of the stroke is quite high, the delivering pressure is reached much earlier in the stroke. This pressure then continuing to the end of the stroke, there is a very uniform load on the piston all the way through and no great difference from beginning to end. The equalizing of the work at the two sides of the machine for both steam and air cylinders is accomplished in the original design of the machine by making the cylinders of the correct relative sizes. Since heat is a product of compression, the compounding of the air cylinders reduces the range of temperatures in these parts also, but this effect of compounding is more fully considered later.

MECHANICAL GAINS BY DOUBLE COMPOUNDING

Looking now at the air end, the phenomena and advantages of compound air compression are so well understood as to need no extended discussion here. It will be enough to emphasize the fact that in the air cylinders inversely the same things are true of pressures and temperatures as have already been noted in connection with the steam cylinders. The result is a reduction of the differences of temperatures and pressures in the air end, all tending toward an improved operation. The cutting down and transferring of the excessive uncompensated pressures in the cylinders from the extreme ends of the stroke, and their more uniform redistribution secured by this process of double-compounding, reduces the terminal and maximum stresses upon the bearings about 45 per cent, noticeably improving running conditions, making the lubrication easy and more effective, reducing wear, and giving great durability while still dispensing with the necessity for close attention.

THE STRAIGHT LINE CAN NOT BE SATISFACTORILY DOUBLE COMPOUNDED

Straight line compressors have been made with tandem two stage air compressing cylinders, and even also with tandem high and low pressure steam cylinders, but these arrangements have greatly complicated the machine, have increased its relative cost for the work it does, have made all the parts more inaccessible than before for adjustment, repair or replacement, and, after all, have left the machine, in its actual running, defective in its characteristic inability to run at slow speed, and to get the expected results at any speed.

FOUR CYLINDERS AN ELEMENT OF ECONOMY

In the duplex machine, as compared to the simple straight line type, while there is a simplification by a reduction of the number of parts as regards flywheel, crank shaft and connecting rods, there are four cylinders in place of two. But here is where one of the most important of the advantages of the duplex machine is found. It happens that this very arrangement at once provides the possibilities for the best economy both in the development of the power from the steam, and in the application of the power to the compression of the air, *simply by virtue of its four cylinders.* To use steam with the best economy, in this line of service, high steam pressure, compound steam cylinders, and a condenser should be used. These conditions, except the latter, may be provided for in new installations; the latter depends upon the water available. To compress the air to the usual pressures, and with the least expenditure of power, compound air cylinders with an efficient intercooler between must also be provided. An economical air compressor of the present day, can not, therefore, have less than two steam and two air cylinders; and if the duplex machine thus insists upon four cylinders, it insists only upon one of the most important conditions of practical economy in air compression.

THE ACCESSIBILITY OF THE DUPLEX

The accessibility of the parts of the duplex machine when running is most important, as it permits perfection of adjustment and prevents serious derangement or loss in economy by providing means for anticipating it. While in the case of the straight line machine some of the parts may be badly worn before any attention is given to them; and in general it may be said that the straight line has to refuse to run before its derangements will be attended to.

ADVANTAGES OF COMPOUND AIR CYLINDERS

The advantages of two stage air compression have perhaps been sufficiently insisted upon and do not need to be given any prominence here. By first compressing to nearly one-half the required load in a low pressure cylinder. then passing the hot resulting air through an efficient intercooler, so that the air enters the final cylinder at about original temperature the power required for the compression is lessened and the air is delivered in better condition for use. The intercooling of the air permits the interception of much of the moisture which it contains; and also the final delivery of the air at a much lower temperature than would result from single stage compression enables it to drop more of the moisture in the receiver. So that when it comes to be used it is practically dry air and gives no trouble from freezing up at the exhaust, or from washing out the lubricant. The reduction of the temperature of the air as it passes through the cylinders and the valve passages reduces the wear of the piston rings, cylinders, stuffing box packing and the valve surfaces by promoting better lubrication through the absence of moisture.

DUPLEX AND HALF-DUPLEX COMPRESSORS

The duplex machine is certainly no more liable to disabling accident than the straight line machine; and in many cases where a breakage or serious accident has thrown one-half of the machine out of use it may still be possible to run the high pressure side independently, when a straight line machine would have been completely laid up. The duplex machine may also be first installed as a half-duplex and run as a straight line machine until the increased demand for air warrants the installation of the second half. The installation of the latter then shows, in smoothness of running, in better speed control, and in higher economy, the advantageous features of the duplex type of machine.

THE DUPLEX A BALANCED STRUCTURE

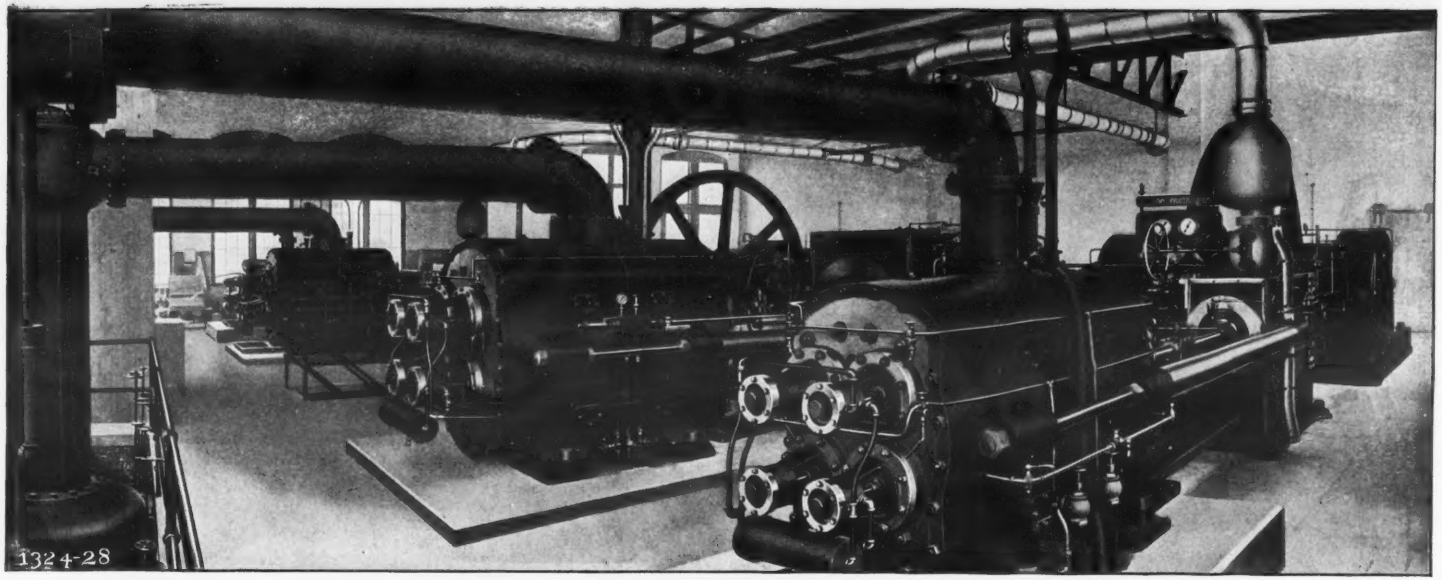
In the duplex compressor not only are the maximum stresses upon each side of the machine reduced, but they occur on the two sides at different times, and largely balance or compensate each other, the combined effect being to reduce the ultimate stresses, to minimize the wear and the chance of break-down, and to prolong the efficient life of the machine.

ALL COMPOUNDING ADVANTAGES POSSIBLE IN THE DUPLEX

The duplex compressor makes possible the compounding of the cylinders either at the air or steam end, or both, without additional complication. The cylinders are there, and in the precise relative conditions most suitable for compounding. Duplex compressors may be, and are actually made either duplex steam and duplex air, duplex steam and compound air, compound steam and compound air, or compound steam and duplex air. The third arrangement is of course the ideal combination for satisfactory and economical air compression, when steam and air pressures are not too low. The location of the cylinders and other parts relatively to each other, is precisely that most convenient for locating and connecting steam receivers, air intercoolers, aftercoolers, and other appurtenances. The attitude of the duplex machine is to invite, to make easy, and to promote the best practice in air compression. The attitude of the straight line machine, on the other hand, is just as distinctly to make difficult, and in some details, impossible, the same advanced and most approved practice.

A SUMMARY OF THE DUPLEX ADVANTAGES

It is really a striking array of advantageous features which can be brought out in favor of the duplex type of air compressor. The following may be recalled among them: greater economy in steam consumption; gains by compounding both steam and air cylinders; the maintenance of a more uniform air pressure; the delivery of dry air; automatic control and efficient lubrication; reduced leakages by the partial balancing of pressures; low friction of valves and pistons; sustained adjustment and tightness of vital parts. These may easily result in a saving of 30 to 40 per cent over the simple straight line machine, and of 15 to 20 per cent over the double-compound straight line. Then the reliability and perfect accessibility of every part, and the saving in supervision and maintenance are also to be considered in its favor. For the straight line it can be said that the first cost is perhaps less, the foundations required are less expensive, and the space occupied is small. The saving in operating the duplex machine will really cover the difference in these costs many times over and, before long, entirely pay for the machine.



LARGEST CENTRAL COMPRESSED AIR POWER PLANT FOR QUARRY WORK IN THE WORLD.

Interior View of the Power House of the Cleveland Stone Company, North Amherst, Ohio.

The two compressors shown have 20 and 44-inch steam cylinders and 39¼ and 24¼-inch air cylinders. Stroke, 48 inches. The air from the plant operates all the machinery in three quarries, one of which is the largest sandstone quarry in the world. This installation was described in COMPRESSED AIR for August, 1905.

A STATEMENT SUBSTANTIATED BY FACTS

This latter is but a plain statement of a simple fact, as may be easily demonstrated by referring to a specific case. The figures will actually show that the difference in the first cost of the machine and its installation is returned in a few months without any but the ordinary conditions as to fuel and labor costs.

PROOF IN A SPECIFIC CASE

Take an average case in which the power consumption is but 500 cubic feet of free air per minute, compressed at sea level to 90 pounds gauge. In a single stage compressor this will require 94 indicated horse-power; in a two stage machine, 81 indicated horse-power. A straight line compressor of this size is usually operated with a simple steam cylinder; and while such machines are usually equipped with Meyer gear permitting economical cut-off, yet the practical running conditions of a straight line are such that not one out of a hundred are, in actual service, run at less than ⅝ to ¾ cut-off. This is a fact of experience, and its result is that straight line machines of this size take, in everyday service, from 40 to 50 pounds of steam per horse-power hour and every well-informed engineer knows that they will require on an average 45 pounds of steam or water per horse-power hour. The duplex, having no "dead center," can be run conveniently at short cut-offs; and in ordinary compressor service, small units and moderate steam pressures, duplex compound steam cylinders will require about 28 pounds of steam per horse-power hour, non-condensing.

These relative figures are as fair to one as to the other—not the best that can be done, but what can actually be expected under ordinary conditions for a term of years.

OPERATIVE CONDITIONS

An average boiler plant will not do better than 7 pounds of water evaporated per pound of coal burned. A boiler horse-power is rated as 30 pounds of steam evaporated per hour. These are all average figures, and comparisons based on them are safe and fair to all.

Results in the present case may be tabulated thus:

Simple Air and Simple Steam: 94 indicated horse-power; multiplied by 45, equals 4230 pounds steam per hour; divided by 30, equals 141 boiler horse-power.

Two Stage Air and Simple Steam: 81 indicated horse-power; multiplied by 45, equals 3645 pounds of steam per hour; divided by 30, equals 122 boiler horse-power.

Duplex Two Stage Air and Compound Steam: 81 indicated horse-power; multiplied by 28, equals 2268 pounds steam per hour; divided by 30, equals 76 boiler horse-power.

OPERATIVE SAVINGS

Saving by Compounding Air End Alone (straight line or duplex) : 13 indicated horse-power; 585 pounds steam per hour; 19 boiler horse-power.

Saving by Compounding Steam End Alone (duplex cross-compound steam simple air) : 1377 pounds steam per hour; 46 boiler horse-power.

Saving by Compounding Steam and Air (duplex double-cross-compound *only*) : 13 indicated horse-power; 1962 pounds steam per hour; 65 boiler horse-power.

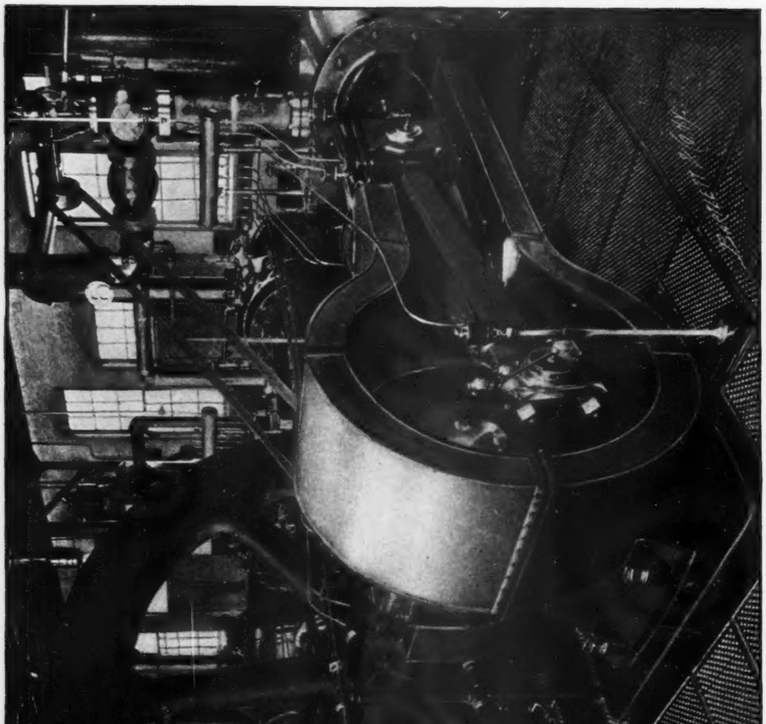
SOME INTERESTING DEDUCTIONS

These figures alone are enough to prove the case, but the buyer of machinery thinks in dollars and cents rather than in horse-power. He is, to be sure, interested in knowing that the duplex compound is "more economical of power," but he knows that "it costs more" than the straight line; and even a full knowledge of the fact that the straight line "double-compound" is mechanically inferior to the duplex or "double-cross compound" may not overcome his financial scruples.

But a complete compressor plant includes boilers and auxiliaries as well as the compressor; and boilers cost money; besides having a voracious appetite for coal. It has been demonstrated that a "double-compound" straight line is not a satisfactory machine; so further comparisons, reduced to money values, may be based on a simple steam two stage straight line and a "double-compound" of duplex type.

SAVING IN BOILER INSTALLATION BY THE DUPLEX

To use this straight line machine, 46 additional boiler horse-power, with larger piping, auxilares etc., must be purchased. The buyer referrng to his catalog table, will see 81 horse-power noted, but will not notice that this is *indicated* horse-power, and at a rating of only 30-45, or two-thirds of the *boiler* horse-power required. So he will probably buy a 90 horse-power boiler, force it up to 122 horse-



A BATTERY OF SEVEN AIR COMPRESSORS IN THE POWER HOUSE OF THE CAMBRIA STEEL COMPANY AT JOHNSTOWN, PA.

Steam cylinders, 20 and 32 inches; air cylinders, 28¼ and 17¼ inches; stroke, 24 inches. Total capacity of plant, 11,700 cubic feet of free air per minute.

power, and then wonder why it fires so hard. This same inference made in buying a "double-compound" would have resulted in getting a good, easy-firing boiler, probably never loaded to its full capacity. The simple steam straight line, therefore, must be charged up with the cost of 46 additional boiler horse-power, with necessary auxiliaries. If their price installed is put at the moderate figure of $10.00 per horse-power, not including cost of auxiliaries and larger piping, there is a total of $460.00, which, credited to the first cost of the duplex double-compound, does not make the latter look so dear after all. In this particular size of compressor it will probably more than cover the difference in price of the two types. Those are installation charges appearing in the items of "first cost."

SAVING OF WATER BY THE DUPLEX

Looking now at the operating charges, it will be noted that 1377 pounds less water per hour is required by the duplex compound. This is 1650 gallons per 10-hour day. In some places water charge is a serious item; at 30 cents per thousand gallons this compressor saves in water about 50 cents a day, or $150.00 per year of 300 days. When water is bad, the less there is to be handled the less boiler repairs involved. In a larger plant, the labor of a fireman may also be saved.

SAVING OF COAL BY THE DUPLEX

The value of the water saved is important, but the amount of coal otherwise needed to evaporate this extra water is still more important. At 1 pound of coal per 7 pounds of water, evaporated, this 1,377 pounds would require 197 pounds of coal per hour, or 1,970 pounds per day of 10 hours. With coal at $4.00 per ton, this is $3.94 per day or $1,182.00 per year of 300 10-hour days. The amount saved by the use of the duplex cross-compound in fuel and water, therefore, is $1,332.00 per year. In five years this amounts to $6,660.00; and if the plant runs double-shift the figure is doubled. Further, as these figures are based upon only 500 cubic feet capacity, it can be estimated approximately for larger volumes. For example, 750 cubic feet equals one and one-half times, 1,500 cubic feet, three times these figures, etc.

WHERE IS THE ECONOMY OF THE "CHEAPER MACHINE"?

Where, now, is the economy of "the cheaper machine"? Even with coal at $2.00 per ton, or only half the figure assumed above, the saving per year in fuel and water appears at $741.00; and the duplex compound is obviously the thing, for this amount will more than overbalance the difference in cost between the two types. Even at this fuel rate its total first cost would be saved in a few years; it would pay to throw out a once a less efficient machine. When coal is at all expensive, it is evident that the buyer should go on to the most refined Corliss type of compressor, running on only about one-half the fuel required by even the good duplex double-compound used in the example—and 500 cubic feet per minute is not a large machine.

It must, however, be kept in mind that to secure these savings it is not enough that a compressor be of the "double-compound" type: but it must be a thoroughly high-class and really economical machine, well and properly designed, and well built. As there are good watches and cheap watches, so are there degrees of quality in all things. As a matter of fact, a really high-class straight-line compressor has been shown by accurate tests actually to deliver its output of air at less fuel cost than duplex compounds which, on the outside, bear the appearance of economical design, and are even sold under "guarantee." Guarantees are of little protection, for once the expenses of foundations, piping, installation, etc., are incurred, and the work has become dependent upon the continued use of the air, tests are not made once in a thousand times; a condition exists of which the average manufacturer is quite willing to take advantage even with impossibe guarantees. If economy is really wanted, it can safely be expected and maintained only in constructions of the highest standard.

The tendency in all power installations of to-day is toward higher economy. Long strides have been made in this direction in recent years, and future progress must consist in a close attention to the smaller economies. It has been shown here how a mere difference in the type of compressor may affect the operating cost of a plant. The wide-awake manager is looking for just such facts as are here set forth, and this discussion should be of assistance in the selection of an efficient air-power equipment.

NEW APPLICATION OF COMPRESSED AIR.

One of the most remarkable applications of compressed air has recently been made by Mr. Phillip Brasher of Brooklyn, N. Y. This is nothing less than applying it for the purpose of protecting objects from wave action, for which he has taken out a basic United States patent,

Mr. Brasher first turned his attention to the study of waves and their effects when he was managing the Parkway Baths at Brighton Beach in 1901. Here there was a bulkhead of considerable length which had been built with no saving of expense but with due regard to the power of the waves. The framework was 15 inch to 18 inch piles joined by 12 by 12 inch timbers, the face consisting of a double layer of 4 inch grooved sheathing, the joints bebeing broken. All timber and piles were creosoted and the bulkhead was backed by a fill of rock, ashes and dirt and when completed should have apparently held back two oceans. But, alas! for the power of mere wood and steel when pitted against the force of ocean waves. Forty feet of bulkhead sheathing was torn away in one night under the action of a fairly heavy sea, leaving only piles and stringers. This was very discouraging, as the repairing of the break of such dimensions meant slow and expensive work. The break was situated at about the center of the structure, and the fact that the bulkhead ruptured at this place was very peculiar as much heavier seas had beaten against it before without doing any damage. But if a wave lands on an object just right, something has to give, and that something is not always the wave. Mr. Brasher began to wonder what could be done to solve the problem, for it seemed to be reducing itself to the old riddle, "if an irresistible force meets with an immovable object, what will happen?" And in the case of the bulkheads, it appeared as though the immovable object was getting the worst of it. In fact, the whole system of breakwaters and bulkheads seemed to be wrong, for they simply opposed force to force and were fighting effect instead of overcoming cause. In treating disease a physician tries to get at the root of the trouble and, if possible, stop the trouble at the start. It seemed therefore that much could be done in the case of fighting waves by breaking them up instead of allowing them to break up the bulkhead.

Now as to means. Anything on or near the surface would be exposed to constant hammering, so, obviously, the strategic point would be some place below the wave action and therefore safe from its destructive force.

And now as to the wave itself. What gives it its power and what is its mode of travel?

There is only one time at which a wave is really dangerous to anything substantial, and that is just as it is curling to break. It is then undergoing a change from what is called an oscillatory wave—or one whose particles merely oscillate, to a wave of translation—one whose particles *travel* along in a certain direction. At that particular time, the momentum attained by the tons of water, elevated to whatever height it may be, and falling from that height, is practically irresistible. So that if it is possible to cause a wave to break *before* striking any object to be protected, the capacity of the wave to do harm, is destroyed and it becomes merely a bubbling mass which looks rough but is really harmless.

Wave motion is described as the transference of energy by vibration: in other words, each particle of the wave merely vibrates and the motion is carried forward by the impact of the vibrating particles. A definition of a wave, given by Anthony and Brackett's "Physics" (page 140), is as follows:

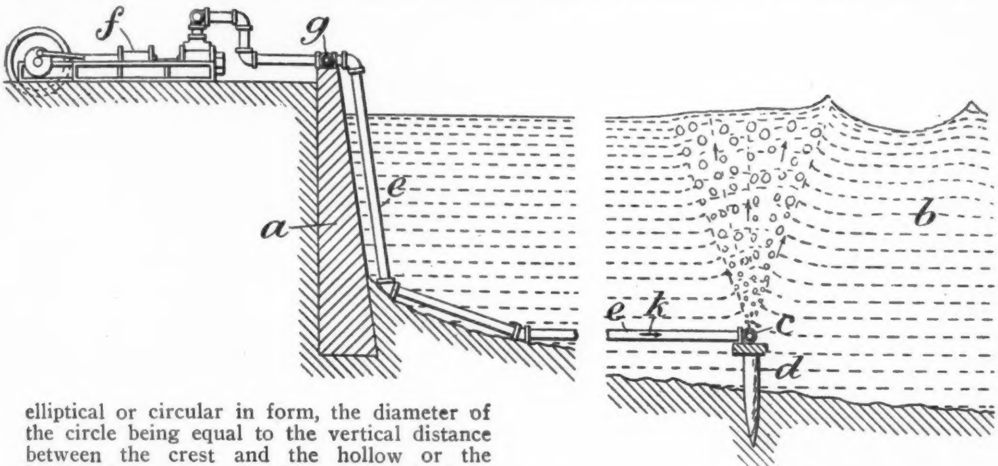
Waves.—When a disturbance is set up at a point in the free surface of a liquid, it moves over the surface of the liquid as a *wave* or series of waves. Each wave consists of a crest or elevated portion and a hollow or depressed portion of approximately equal length, and the distance from a particle at the summit of one crest to a particle at the summit of the next succeeding crest, or the distance between particles in successive waves which are in the same condition of motion, is called a *wave length.* A line which is drawn along the crest of any one wave or through the particles in that wave which are in the same condition of motion, and which at every point is at right angles to the direction in which the wave is propagated, may be called the *wave front.*

The formation of waves is explained by inequalities of hydrostatic pressure arising in the liquid if by any cause one part of it be elevated above the rest. H. and W. Weber examined the peculiarities of waves in water and the motions of the water particles in them by the aid of a long trough with glass sides; by immersing one end of a glass tube below the surface, raising a column of water in it a few centimeters high by suction, and allowing it

to fall, they excited a series of waves which proceeded down the trough and could be examined through the sides. The motions of the particles in the wave were studied by scattering through the water small fragments of amber, which were so nearly of the same specific gravity as the water that they remained suspended without motion except during the passage of the wave, and took part in the motion excited by the wave as if they had been particles of water. It was found that the wave motion transferred from one portion to another of the water, and did not involve a displacement of the particles concerned in it, —at least when the successive waves had the same length. In that case—which is the typical one—the particles in the surface of the water described closed curves, which were elliptical or circular in form, the diameter of the circle being equal to the vertical distance between the crest and the hollow or the height of the wave. In the upper part of the circle the particle moved in the direction in which the wave was moving, in the lower part of the circle in the opposite direction. The velocity of the wave was found to be dependent on its height and on the period of oscillation in the wave, and to be independent of the density of the liquid. The disturbance of the liquid bv the wave is not merely on the surface, but extends to a considerable depth; as the depth increases the elliptic paths of the particles approach more and more closely to short horizontal lines.

The theory of these waves is extremely complicated, and has not yet been satisfactorily worked out; but we can indicate in a general way their causes and the mode of their propagation. Imagine a small hillock of water elevated at some point in the surface, and consider a particle at the base of this hillock; the hydrostatic pressure arising from the elevated column near it will tend to move it upward and outward from the center of the hillock. It will accordingly begin to move in the upper half of its circular path and in the direction in which the wave is propagated; the precise form of its path being determined by the changes of pressure which it experiences and by its inertia. Since the pressure which sets it in motion will be different for different heights of the hillock which gives rise to it, the velocity of the particles, and therefore also the velocity of the wave, will depend on the height of the wave, being greater as this is greater; the velocity of the wave is also greater as the wave length is greater. Since the pressure behind the particle and the inertia are both proportional to the density of the liquid, it is evident that the acceleration of the particle will be the same under similar circumstances, whatever be its density, so that the velocity of the wave should not depend on the density of the liquid.

The form of a wave is greatly modified by the character of the channel in which it moves, on account of the motion of the particles extending to a considerable depth, and on account of their viscosity. On the free surface of a large and very deep body of water the successive waves have the same form; the slope of the crest is a little steeper than the slope of the hollow, and its length is less than that of the hollow. As the depth decreases, the slope of the front of the crest becomes still steeper because of the restraint which then is imposed upon the movement of the particles in the lower half of their paths, and at last the forward motion in the crest so much predominates that the wave curls over and breaks."



An actual demonstration of the effect of compressed air on wave motion can be observed at several points above the tunnels which are being run under the river from New York City. The compressed air used in the tunneling escapes in various ways and rises, sometimes after quite a long journey through fissures or strata, to the surface, producing—particularly if there is a considerable amount of air—a complete elevation of the water directly above the escaping columns and a tremendous disturbance of irregular bubbles. Waves which imping on this disturbed area, collapse like balloons which have been pricked

with pins. In this case the discharge of the air is not scientifically arranged, but even under these disadvantages the effect is absolute and undeniable.

Now as to the uses. In the first place, consider a disabled ship drifting on to a lee shore. She could simply throw out a sea anchor to which was fastened a distributing pipe for the compressed air and which could be held far enough away from the ship by means of a secondary anchor. Thus protected, the ship could lie in perfectly smooth water till repairs were made or the sea subsided. In the same way, stranded vessels could be protected from the pounding of the waves, till floated. Lightships could be surrounded by a circle of pipe and lie in the center of an absolutely calm surface. A space in front of life-saving stations could be covered so that lifeboats could be launched and started, for once started they could brave almost any sea. Bulkheads and breakwaters already built, could be afforded absolute protection by means of parallel pipe in front of them at a suitable distance, and artificial harbors could be constructed by simply running a line of pipe between two projecting headlands, and, the writer, believes, that in the not distant future there will be harbors constructed in the middle of the ocean, in vicinities of more than ordinary roughness, by means of pipes suspended from a series of floats so placed that both floats and compressor will be protected from any danger of wave action.

Mr. Brasher expects to establish an experimental station sometime during the coming summer, in which he will use various kinds of pipe, placed in various positions and under all conditions, in order to discover the most efficacious system under varying conditions. As the complete cotinuity of the particles is absolutely essential to wave motion, the position and kind of pipe which most completely destroys that continuity, is the one which will give the greatest satisfaction.

RETURN AIR.

The fact that compressed air does not condense and disappear as steam does, gives it a great advantage in its employment for intermittent and occasional work, says *Cassier's Magazine*. This advantage is fully appropriated in the air brake and in switch and signal work, where the air charges nothing for standing always ready, but only for work actually done.

The same condition of advantage should apply also in making available the elasticity or expansive force of the air, but in this field little progress has been made. The earliest general applications of compressed air were, and some of its developments of highest usefulness even to-day are still, self-evidently extravagant and wasteful. Attention has been called over and over again to the enormity of using air for driving the ordinary steam pump, from the fact that on the completion of each stroke the cylinder is entirely filled with air at the full pressure of the supply, whether this full pressure is required for the work or not, and the air is then thrown away at that full pressure with none of its expansive force made use of. The same waste of air practically occurs when the ordinary rock drill, of whatever make, is driven by compressed air. The air there also is discharged at full pressure, and, so far as power development is concerned, it might as well not be elastic.

The return air systems, which may be said to be only in process of development to-day, with the possible applications not as yet all thought out, seem to promise phenomenal results as compared with established practice. Return-air is the winning feature of the electric air drill. The return-air pumping system seems to be the most complete and convenient example of the transition from the old to the new. The raising of water by the direct pressure of air long seemed the most hopeless case of all. When compressed air has been admitted to the top of a chamber which is full of water, when the water has been driven by the air pressure up a pipe to some higher level of delivery, and when it then becomes necessary to get rid of all the pressure in the chamber, so that water will again flow in and fill it, what is there to do but to let the air escape into the atmosphere?

There has been but the one self-suggesting answer: open the valve and let the air go. We have had for a generation or two various devices all operating upon the same general principle of driving the water out and up by the direct pressure of the air and then letting the full pressure air escape. While this has been so long the only apparently possible answer, it has, of course, never been satisfactory, and the general use of air pressure for raising water has not extended rapidly on account of the cost of operation.

The real, up-to-date and more satisfactory way of answering the question is the asking of another: Why not, instead of letting the air escape into the atmosphere, pipe it back to the intake side of the iar compressor? There is no "why not," and this is accordingly done with most satisfactory results, transforming the wasteful device into one without that reproach.

COMPRESSED AIR

Established 1896.

A monthly magazine devoted to the useful applications of compressed air.

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FORTUNE is not always on the side of the publisher. In fact, he seems to have a surfeit of the other thing if our recent experience is any criterion.

It has been our endeavor that COMPRESSED AIR should make its appearance as close to the tenth of the month of publication as possible, but recently it has been coming out nearer to the tenth of the month *after publication*.

Labor trouble is responsible for this, a strike among the linotype operators, who have most to do with setting up the reading matter of the paper, having caused us much exasperation and delay.

These troubles are now, happily, over, and we hope that in the future COMPRESSED AIR will make its monthly appearance with more regularity and dispatch.

EDUCATION OF ENGINEERS.

In the October issue of COMPRESSED AIR we published an editorial on this subject in which we pointed out that, with the exception of New York University, there were practically no colleges in the country giving courses in the theory and practice of compressed air. We are now in receipt of a letter from H. J. Thorkelson, Assistant Professor of Steam Engineering at the University of Wisconsin in which he states that for some time past his department has been delivering lectures and giving practical instructon in this most important subject.

A synopsis, furnished by Professor Thorkelson, of his courses is most interesting, showing as it does, the thorough manner in whch the subject is covered. The first lecture consists of an historical account of the development and uses of compressed air and is followed by three or four lectures on air, its nature and composition. This includes the thermodynamics of perfect gases as applied to air in adiabatic and isothermal changes. Such terms as "free air" and dry air" are explained, and charts given to the students showing graphically the temperature change as air is compressed, also the work required to compress a given amount of free air to various gage pressures. This leads to a discussion of the ideal method of securing compressed air.

The above might be termed preliminary work, and is followed by a discussion of disc, centrifugal and positive volume fans and blowers, their theory and the formulæ required for calculating the capacity, and horsepower of these different types. Compound fans are next taken up, after which the subject of piston compressors is considered. In doing this the multi-stage system of compression is explained, and the use and construction of intercoolers, afercoolers and other attachments. The various types of piston compressors such as the "Straight Line," "Duplex" and other forms are illustrated, together with valve details and computations. Regulators, unloading devices, etc., are studied, after which the hydraulic system of compressing air is taken up. This subject is discussed by studying the details of construction from the most successful installations.

The work is then followed by the subject of pipes, and pipe transmission, with calculations for friction and other losses as well as some of

the more important practical details of designing and installing pipe systems.

The rest of the course is devoted to a study of compressed air as applied to pumping, pneumatic tools, caisson work, tube transmission, street cars, air brakes, signalling and other uses; the description of many of these subjects beng supplemented by the actual operation of tools in the lecture room.

With the new material and lantern slides which are constantly being added to the equipment of the University, it would be hard to see how this course could be made more comprehensive and useful. We consider the University of Wisconsin should be congratulated upon taking the initiative in furnishing students of engineering with a foundation by which their work in after life may be made considerably easier, especially if it brings them into contact with pneumatic machinery.

THE CAPITALIST.

The worthy gentlemen in this country who are giving themselves so much concern because of the existence of the capitalistic class, says the *Army and Navy Journal,* would do well to study the explanation given by Herr Waldemar Schutz, a German who has been seeking an explanation of the poverty and starvamous possibilities of wealth. In an article in the Gegenwart of Berlin, translated in part by the *Review of Reviews,* he finds the explanation of this anomaly in the fact that the mechanical work of India is done by exclusively individual labor and not by the combined labor of individuals under the direction of capitalists. "In Europe and America the ideal business man is an individual who is intimately acquainted with all branches of his profession and who is constantly in touch with the developments of his particular line, one who selects his men so that each workman will be given work he is best qualified to do; who studies the market demand for his goods, and so forth. And it is clear that when business is conducted in this way it will probably produce a more perfectly developed organization than when it is controlled by an uneducated workman who has mere dexterity of hand at his command. In India the control of trade is in the hands of people who have no opportunity to study new methods of production, no way of seeing new mechanical tools, no possibility of studying market fluctuations, and who, because of their very independence, cannot be given the work for which they are best qualified." But there are indications of a change in India, and while we are proposing to inaugurate the millennium by killing off the capitalist, India is hoping for his advent that he may organize her industries and make them effective for the increase of her wealth and the substitution of general comfort for the wretched poverty which is the lot of the lower class Indian. The organization of modern commercial and industrial society seems to us to run parallel with the growth of what its critics call militarism. It vastly increases the power of the mass as well as the efficiency of the individual, while depriving him in a measure of his untamed freedom of action. Those who have so much to say about the rich growing richer and the poor poorer under our system would do well to compare our average condition under cooperative labor with that of the three hundred millions of India who have not yet developed the system of capitalized organization.

A novel feature in tunnel design devised by Mr. Chas. M. Jacobs, the chief engineer to the Pennsylvania tunnels under the Hudson River, is found in the screw piles, which will be placed at intervals of 15 feet throughout the length of the tunnels. While the silt forming the bed of the river is sufficiently tenacious to hold the tunnels in perfect alignment during construction, it was not considered firm enough to do so when the tunnels are in use. To forestall this possible danger, screw piles will be sunk to a solid foundation, and upon them the tunnel proper will rest. The piles will be 27 inches outside diameter, and the shell will be 1¼ inches thick. The sections will be 7 feet in length, and will be bolted together through internal flanges. The lowest section will be cast with one turn of a screw 4 feet 8 inches in diameter.

The "shell," or jacket guides, of a rock drill, when worn, allow the machine too much play, which is likely to break the feed screw and considerably affects the efficiency of the machine, inasmuch as it will waver slightly, each blow of the drill increasing the friction and thus reducing the efficiency.

NEW PUBLICATIONS

Modern American Lathe Practice, by Oscar E. Perrigo, M. E., 416 pages, fully illustrated, published by The Norman W. Henley Publishing Company, New York; price, $2.50.

This work is certainly a very complete treatise on the subject of the modern lathe, its design, development and use, and will doubtless meet with great favor at the hands of engineers and mechanics. The book opens with a chapter on the history of the lathe, up to the introduction of screw threads, and then traces its development from that time to the present. This is followed by a chapter on the classification of lathes, in which the author divides them into four general classes, with eighteen subdivisions of these classes, giving a short description of each. The chapters covering lathe design are most complete and occupy approximately 130 pages, practically every part which enters into the construction of a modern lathe being treated in greatest detail. The rest of the book, some 200 pages, is taken up with lathe practice, high speed cutting tools, proper feeds and cutting speeds, testing lathe, turning tapers, crank shafts, boring cylinders and other important work. The book should be of great value to shop men in general, as it is the only complete work ever written upon the subject, and contains a vast amount of valuable information.

TRADE PUBLICATIONS

Kilbourne & Jacobs Manufacturing Company, Columbus, Ohio.—Catalog No. 36, 6x9, 96 pages, devoted to a full description of the mine and industrial railway cars which this company manufactures. Among the cars included in the catalog are various dump cars, rocker cars, ash cars, contractors' cars, cable bottom cars and cars for coke ovens, foundries and manufacturing plants.

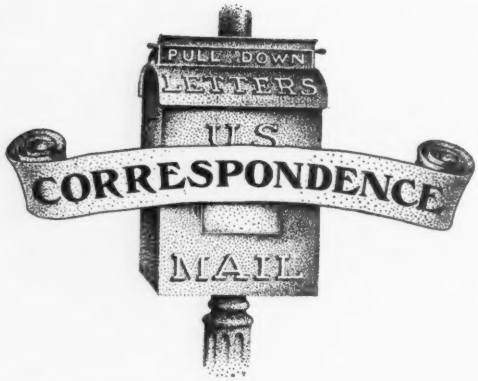
Baldwin Locomotive Works, Philadelphia, Pa.—Record No. 60, 6x9, 32 pages, entitled "The Actual Efficiency of a Modern Locomotive." This booklet takes up the subject of theoretical efficiency, first costs, interest on investment, depreciation in value, fuel, supplies, estimated cost of cylinder and engine oil per 1,000 engine miles, hauling capacity and cost per ton mile, etc. It is a most interesting and valuable booklet for any one to possess.

Weston Engineering Company, 56 and 58 Pine street, New York—Handsomely printed catalog, 22 pages, 9x12, profusely illustrated, describing the Blake-Denison Continuous Weigher, for weighing material handled by conveyors. This apparatus automatically weighs and records the quantity of ore, coal or other material passing over any conveyor, giving a continuous record of the aggregate net weights. A record that can be consulted hourly, daily, weekly or as may be desired. It is claimed that it will weigh within one-half of one per cent.

Word Brothers, 60 Castro street, San Francisco, Cal.—Small booklet, 24 pages, devoted to a description of the Word Brothers' Drill-Maker and Sharpener, which forges and sharpens all styles of rock drills up to 10 feet in length, while their special machine accommodates drill steels up to 40 feet in length. These machines will sharpen from 600 to 800 steels per day and will forge from 500 to 700 new drills per day from blank steel bars.

Joseph Dixon Crucible Company, Jersey City, N. J.—Souvenir book, 6x9, 40 pages, entitled, "Crucibles, Their Care and Use," by John A. Walker. This book should be in the hands of all interested in the melting of various metals, as it instructs the users of crucibles as to their proper use and the danger of abuse of crucibles. It tells what graphite is and why crucibles are made of it. This work was prepared by Mr. John A. Walker, vice-president, treasurer and general manager of the Joseph Dixon Crucible Company, who is thoroughly fitted by long years of experience in crucible making to be regarded as an authority on the subject.

THE Hurry and Seaman compressed air device for cement has superseded the natural draft system at the plants of the Lehigh Portland Cement Co., says the *Engineering Record.* The latter system, in which very high stacks are utilized in order to get the draft, was invented by Mr. Chas. A. Matcham, the former general manager. Col. Harry C. Trexler, president of the Lehigh compony, states that the Hurry and Seaman method was installed due to the fact that the natural draft system did not come up to expectations, either in economy or in efficiency.



To the Editor of Compresser Air:

Dear Sir—I have at hand my first copy of COMPRESSED AIR, with which I am very much pleased. I wish to ask if you answer practical questions through the medium of your paper, such questions for instance as the following:

What is the reason that heavy flywheels are used on single stage compressors?

What should be guarded against in lubricating the air cylinders?

What advantage is there in multi-stage compression?

Simple questions, no doubt, to some, not so to others. An answer to these questions and others along the same line would be very much appreciated, if it is your custom.

T. F. HAGGART.

The reason that heavy flywheels are used on single stage compressors is due to the fact that in these machines when the piston is at the end of the stroke the pressure in the steam cylinder is at its lowest point, while the pressure in the air cylinder is at a maximum; it is therefore necessary to make the flywheel extra heavy in order to carry the machine over this point.

In a duplex compressor, where the cranks are quartered, heavy flywheels are not required, as the steam pressure in one steam cylinder is at a maximum when the steam pressure in the other steam cylinder is at its lowest point.

In the lubrication of air cylinders care should be taken to use only oil of light body and high flash point, and, under no circumstances should kerosene be introduced into the cylinder. If trouble is encountered, due to sticky discharge valves, these should be removed from the cylinder and cleaned with soap and water. If it is not practicable to shut down the machine, soap suds may be fed to the cylinder through the lubricators, and then the machine run on oil for a short time before shutting down, to prevent the valve rusting. It is very good practice to feed soap suds into the air cylinder for a couple of hours each week in order to keep the valves from becoming gummed up.

The advantages of multi-stage compression are so many and so great that it is possible to write a book on the subject, and we should like to refer you to any good work on compressed air, such as Saunders' Encyclopædia of Compressed Air Information, Richards' Compressed Air, etc. Briefly, however, there is a gain of about 15 per cent. in a two-stage over a single-stage air compressor when operating within the usual range of pressures. This is due to the fact that air as it is compressed becomes heated and therefore occupies a greater volume than it would if cooled. The compound air compressor cools the air after it has been partially compressed, and it consequently enters the high-pressure cylinder at its original temperature, so that its final temperature upon compression is considerably lower than if it had been compressed in a single-stage machine, and a greater volume of air may be compressed at an expenditure of the same amount of power.

RESCUE WORK IN MINES.

Reference was made in a previous issue to the activity in mine rescue work. We are now able to announce that a new liquid air rescue apparatus, embodying an altogether new principle in regenerative appliances has been perfected. It is known as the "Aerolith," and the entire apparatus, weighing only some 14 lbs. can be easily carried on the back. The claim is made that it will give an absolutely pure and cool air supply during three hours' working, and there is the advantage that its use calls for no special training on the part of the miner. The apparatus is to be made the subject of exhaustive tests in England, one of the appliances having been purchased by the Royal Commission on Accidents in Mines for that purpose, and a large liquid air plant has been installed at the Rothschild Mines in Austria. Authoritative pronouncement as to the real utility of the apparatus is likely, therefore, to be forthcoming in the near future.

CHIPPINGS.

A novel and improved fog signal is just installed at the Needles light-house, Isle of Wight. It consists of a set of reed trumpets, worked by compressed air, and can be started instantly when fog descends, giving a blast five seconds long every fifteen seconds, which can be heard ten miles—treble the distance of the old fog-bell signal.

Compressed air is still more extensively used than electricity as the motive power for coal-cutting in Great Britain. In 1905, there were 555 compressed air machines, while only 355 electric machines were in use. However, the latter are making greater strides than the former, for out of the year's increase in the number of machines in use, 85 were driven by electricity and 70 by compressed air.

The pipe system, which serves to supply compressed air to the various stations for the use of the locomotives in the plant of the Washoe Copper Company, is composed of pipes varying from 6 in. to 2 in. in size. Even at the high pressure of 800 to 900 lb. per square inch it has developed practically no leaks. The air is furnished by two four-stage compressors, having cross-compound steam cylinders, equipped with Corliss valve gears. The compressors are provided with automatic regulators to insure constant high-pressure air.

COUNTING REHANDLED MATERIAL TWICE.

More than 13,000 tons are handled daily at the than 13,000 tons are handled daily at the Washoe smelting works, Anaconda, Mont., by 13 compressed-air locomotives, 12 of which weigh 13 tons each, and one 21 tons. Each locomotive carries two storage tanks for its air supply, the air being taken from a pressure system of pipes laid conveniently to the tracks, and having stations at which the locomotive stops to get its air supply. This supply is carried at from 800 to 900 lbs. pressure per square inch. A reducing valve between the storage tanks and the cylinder reduces the pressure to 150 lbs. A fresh supply of air is taken at times ranging from 20 to 60 minutes. For this particular service, where the distances are short, and where the cars are frequently stopped and started, the compressed-air locomotives have been found most satisfactory for convenience, reliability and simplicity of operation. They have been in constant service since 1900, and have needed only the natural running repairs.—*Engineering and Mining Journal.*

Recent experiments in France have developed a new respiratory apparatus for underground work. It consists of an india rubber bag, worn in front about waist high, and supported by a strap over the shoulder. The miner breathes the products of respiration into the bag by means of a mouthpiece. This air passes through two tubes containing grains of oxylith, which has the property of retaining moisture and carbonic acid, while setting free a corresponding quantity of oxygen. The vitiated air therefore becomes renewed when stored in the bag.—*Engineering and Mining Journal.*

A WATERPROOF CEMENT.

A water-proof cement that has been patented in Germany consists of vegetable wax and caustic lime in boiling water, which is added to unground portland cement clinker; the whole being then ground together. The inventor makes the claim that a ½-in. coating of this cement placed on a brick wall will render it absolutely water-proof.

A ROCK DRILL SCHOOL.

According to the Transvaal Advertiser, in many trades and professions the apprentice has to pay for his teaching. In marked contrast to this a rock-drill school has been started in the Crown Deep mine (says "S. A. Mine") where thrifty and industrious men may learn the ins and outs of such a remunerative trade as rock drilling, and get paid ten shillings a day while learning. The learners in the "scholar stope" at the Crown Deep are under the supervision of an expert rock-drill miner, and several of the pupils have attained to a degree of proficiency which fits them to fill other and more responsible positions. The mine captain of the Crown Deep is keenly alive to this, and all who become capable workmen will receive capable miners' work at capable miners' pay.

GORDON-HELLMAN ROCK DRILL.

Alfred Lewis, in a recent article in the *London Mining Journal,* states that the Gor-

don-Hellman rock drill promises to solve the labor difficulty in the Transvaal. It may take the place of the Chinese, reducing the number of stoping boys required from six to one. One boy can do only one hole in a shift by the usual method, while this machine, costing two hundred dollars, with one boy, does from six to nine holes during the same period.

BRITAIN BEMOANS THE LOSS OF MEXICAN TRADE.

In the British consular report, published here, it is stated that there is a great falling off in the trade between Mexico and Great Britain both in quantity and value as compared with that of the United States. The report states that the geographical advantages possessed by the United States offset the great transportation facilities which Great Britain can offer.

COMPRESSED AIR VS. EXHAUST PRESSURE ON MOTOR CARS.

Exhaust pressure is used for a variety of purposes, the chief being to provide the petrol feed from the usual rearwardly-placed fuel tank. In addition to this, in spite of the increasing use of mechanically-operated lubricating devices, many lubrication systems depend upon the pressure of the exhaust gases for their operation. Exhaust gases for these purposes, however, possess certain drawbacks, such as the formation of deposits in pipeways and in the tanks and lubricators themselves, even with the best of filtering devices interposed. The use of some compressed air system would seem, then, to provide the most practicable and altogether satisfactory pressure feed, as it is absolutely free from the disadvantages inherent to the exhaust-pressure system. There is no denying that there is some slight addition to the number of moving parts about the engine, but the mechanism required for the minute air pump that is sufficient to maintain a pressure feed is so insignificant that it need be given no more consideration than the more usual pressure valve. That such a device is an advance on usual practice cannot be denied. It was interesting to note that of the only two chassis so fitted at the recent Olympia Show both were British, one being the Scottish Albion, and the other the English Thornycroft.

DEEPEST CAISSON RECORDS BROKEN.

Part of Foundations for Fulton Street Terminal of McAdoo Tunnel 98 Feet Below Curb.

All records for the depth of foundations in the city of New York were broken recently, when a caisson for the building which is to be over the downtown terminal of the McAdoo tunnels was sunk ninety-eight feet.

The previous record was ninety feet, attained in many of the excavations for the skyscrapers which are under construction in Broadway. The caisson will be filled with concrete and will form the support at Church and Fulton streets for the corner of one of the twin buildings which the tunnel company is erecting.

It will also constitute a part of a great cofferdam which is to surround the station for the electric cars which are to come from New Jersey beneath the Hudson. This cofferdam itself is the largest ever made for a New York office building. It is a solid wall of concrete which rests upon the rock from seventy-five to ninety-eight feet below the curb, and it is ten feet thick.

ALTHOUGH the cost of underground pumping by compressed air may be considerably reduced by the use of reheaters, the conclusion should not be jumped at that is always advisable to install them. In places where the ventilation is poor they are entirely out of the question. It has been observed that the gases of combustion have a deicdedly injurious action on hauling ropes, if allowed to pass up the same shaft, and it is, no doubt, this fact which has prevented more attention being paid to re-heaters. Another point is the fact that most underground air pumps are of small size and a saving of 30 per cent. in operating expenses does not mean much when reduced to dollars and cents.—*Mining Reporter.*

THE new Northern Pacific yards at Laurel, Montanta, will contain a car-cleaning plant with a large air-compressor, capable of cleaning not only passenger cars, but also of cleaning and disinfecting stock cars in accordance with the State law. The plant will have a capacity of 100 stock cars a day, besides all the passenger cars which it will be necessary to clean. In the past the cleaning of stock cars has been done by hand, but this system has been found too slow and expensive.

U. S. PATENTS
ESPECIALLY PREPARED FOR
COMPRESSED AIR

Full specifications regarding any of these patents may be obtained by sending five cents to the Commissioner of Patents, Washington, D. C. (Stamps will not be accepted.)

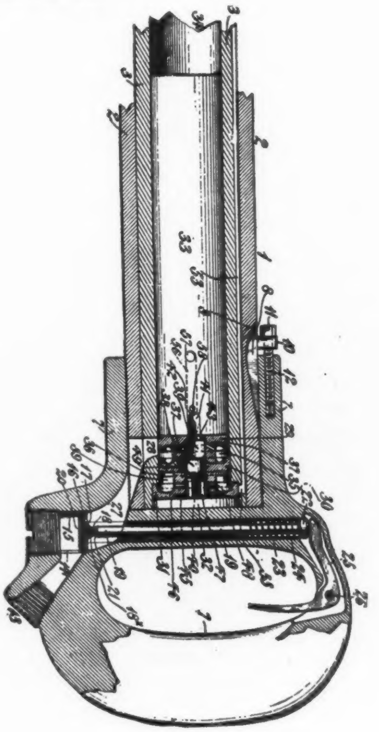
842,324. AIR-GUN. WILLIAM F. MARKHAM, Plymouth, Mich., assignor to The Markham Air Rifle Company, Plymouth Mich., a Corporation of Michigan. Filed Feb. 23, 1906. Serial No. 302,600.

842,343. AIR-INLET AND BEER-OUTLET BUNG FOR BARELS. GUSTAVE A. W. SCHILLING and JOHN H. FLACH, Denver, Colo., assignors of one-third to Louis Becker, Denver, Colo. Filed Feb. 28, 1906. Serial No. 303,424.

842,352. CARRIER FOR PNEUMATIC-DESPATCH APPARATUS. CHARLES F. STODDARD, Boston, Mass., assignor to American Pneumatic Service Company, Dover, Del., a Corporation of Delaware. Filed May 17, 1904. Serial No. 208,369.

842,392. EXPLOSIVE-ENGINE. JOHN ECKHARD, Buffalo, N. Y., assignor of one-half to Joseph P. Fell, Buffalo, N. Y. Filed June 29, 1905. Serial No. 267,633.

842,626. PNEUMATIC HAMMER. JOHN. F. CLEMENT, Philadelphia, Pa. Filed Apr. 15, 1905. Serial No. 255,800.



Claim.—1. In a pneumatic hammer, a cylinder adapted to be manually held and having a piston therein and a valve mechanism, comprising a main valve, and a plurality of auxiliary valves, the latter being carried by said main valve, said valve moving in substantial alignment with said piston.

12,599. AIR-COMPRESSOR. EBENEZER HILL, South Norwalk, Conn. Filed May 15, 1906. Serial No. 317,004. Original No. 700,927, dated May 27, 1902. (Re-issue.)

842,160. PNEUMATIC-ALVE MECHANISM. BERT AIKMAN, Chicago, Ill., assignor of one-half to John S. Hamlin, Chicago, Ill. Filed Oct. 21, 1905. Serial No. 283,834.

842,655. PNEUMATIC HAMMER. MARTIN HARDSOGG, Ottumwa, Iowa. Filed July 28, 1904. Serial No. 218,546.

842,774. AIR-BRAKE SYSTEM. WILLIAM H. EICHELBERGER, Royalton, Pa., assignor of one-half to Milliard F.Meinsler, Middletown, Pa. Filed Oct. 10, 1905. Serial No. 282,143.

843,522. COMPRESSED-AIR BRAKE FOR GUNS THAT RECOIL ON THEIR CARRIAGES. JOSEPH A. DEPORT, Paris, France. Filed Dec. 11, 1906. Serial No. 347,366.

843,481. AUTOMATIC AIR-BRAKE MECHANISM. WILLIAM MCCOOK, Walton, N. Y. Filed Oct.16, 1905. Serial No. 282,955.

843,180. AIR-WASHER. CHARLES W. ROGERS, Chicago, Ill., assignor to Mathis Brothers Company, a Corporation of Indiana. Filed Oct. 5, 1906. Serial No. 337,525.

842,072. ROCK-DRILL SADDLE. GEORGE S. POWER Passaic, N. J. Filed Mar. 31, 1906 Serial No. 309,082

842,949. HYDRAULIC PRESS. BERTHOLD GERDAU, Dusseldorf, Germany. Filed Oct. 11, 1899. Serial No. 733,241.

842,923. COMBINED AUTOMATIC AND STRAIGHT-AIR BRAKE. WALTER V. TURNER, Wilkinsburg, and EDWARD A. WRIGHT, Edgewood Park, Pa., assignors to The Westinghouse Air-Brake Company, Pittsburg, Pa., a Corporation of Pennsylvania. Filed May 6, 1904. Serial No. 206,655.

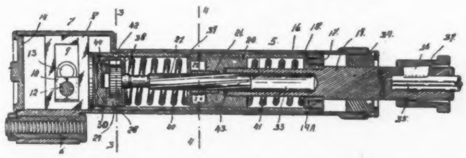
SEVEN—APRIL COMPRESSED AIR

844,410. PNEUMATIC CLEANER. PAUL SCHAUER, Berlin, Germany. Filed May 7, 1906. Serial No. 315,658.

844,466. APPARATUS FOR MOISTENING THE AIR AND DISTRIBUTING WATER AND OTHER FLUIDS. CARL H. PROTT, Rheydt, Germany. Filed Sept. 21, 1905. Serial No. 279,459.

844,483. AUTOMATIC AIR-COUPLING DEVICE. WILLIAM H. SUTHERLAND and ROBERT N. VAN HORNE, Sioux City, Iowa. Filed June 16, 1906. Serial No. 322,117.

844,582. ROCK-DRILL. HENRY DEITZ, Denver, Colo. Filed June 2, 1905. Serial No. 263,366.

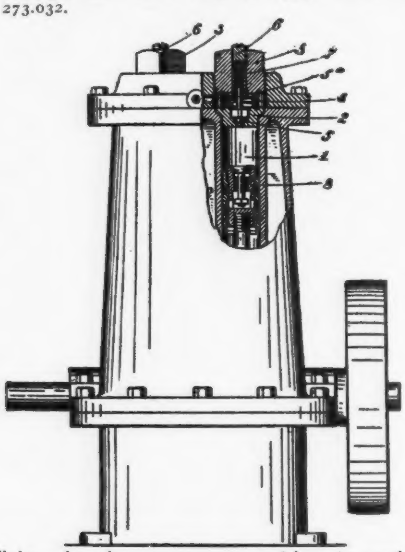


Claim.—In a rock-drell, the combination with a casing, of a reciprocable yoke located therein, a hollow member connected to move with the ykooke, a piston located in the hollow member, a drill-holder connected with the piston, a loose collar surrounding the drill-holder, the latter having a stop to limit the forward movement of the collar thereon, the hollow member also having a stop for the loose collar forward of the latter, a rifle-bar and ratchet carried by the hollow member and connected with the drill-holder for rotating the latter, and a yielding connection between the drill-holder piston and the hollow member, substantially as described.

844,648. AIR-COMPRESSOR. JOSEPH O. BANNING, Zanesville, Ohio. Filed Dec. 18, 1905. Serial No. 292,329.

Claim.—In a fluid-compressor, the combination of a fluid-compressing chamber, a p:ston therein, and two valves for said chamber one of wh:ch is provided with a port and heat to receive the other, independent springs to press on said valves, and two threaded nuts one within the other to press, one on one of the springs, and the other on the other of the springs, whereby the pressure of said valves on their seats may be independently regulated.

844,724. AIR-COMPRESSOR. HENRY H. HERRMANN, Chicago, Ill. Filed Aug. 7, 1905. Serial No. 273.032.



Claim.—An air-compressor comprising, in combination, a pressure-storage chamber provided with a valved pressure-inlet opening and a valved pressure-outlet opening, a bellows mounted immediately upon the wall of sa:d chamber to constitute it one of the bellows-walls, said bellows covering said inlet-opening, and being provided with a valved air-inlet opening, a handle-equipped rotatable drive-shaft, a gear loosely mounted thereon and carrying a pallet, a ratchet-wheel on said shaft engaged by said pallet, a fixed gear and a windlass on sa:d shaft, weighted-pulley mechanism having a cable connection with the windlass for operating the drive-shaft, a driven shaft, a fast gear near one of said driven shaft meshing with the loose gear on said drive shaft, a loose gear on said driven shaft carry:ng a pallet, a ratchet-wheel on the driven shaft engaged by the last-named pallet, a fast year on the opposite end of the driven shaft, a gear operated by said last-named gear and carrying a pitman, and a link connecting said pitman with said bellows, for the purpose set forth.

844,745. SPRAY FOR ROCK-DRILLS. EDWARD G. A. REES-GIBBS, Roodepoort, Transvaal. Filed Sept. 17, 1906. Serial No. 335,023.

844,776. THROTTLE-VALVE AND AIR-STRAINER FOR PNEUMATIC DRILLS. CARL A. CARLSON, Holyoke, Mass. Filed Dec. 7, 1905. Serial No. 290,735.

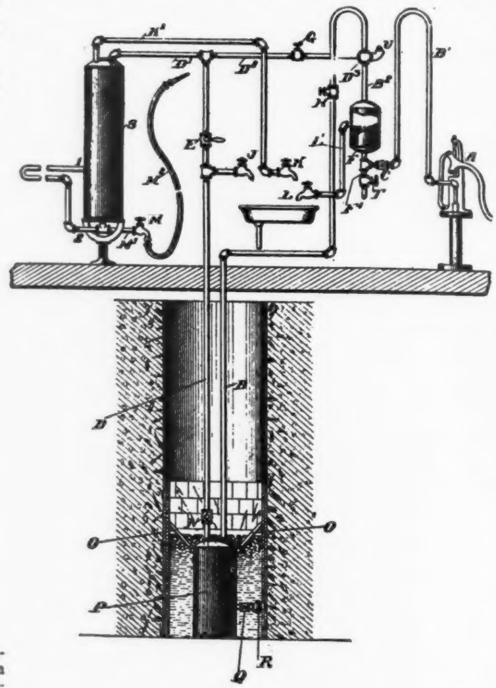
844,801. AIR-COMPRESSOR GOVERNOR. EBENEZER HILL, Norwalk, Conn. Filed Nov. 7, 1905. Serial No. 286,185.

Claim.—The combination with an intake-valve of an air-compressor cylinder, of mechanism adapted to hold said valve open, a speed-governor, and means controlled by the governor and connected with the aforesaid mechanism which when the governor is collapsed causes said mechanism to hold the valve open, substantially as specified.

844,820. METHOD OR FORMING PNEUMATIC TIRES OR TIRE-CASINGS. ARTHUR H. MARKS, Akron, Ohio. Filed Nov. 19, 1906. Serial No. 344,140.

844,879. VALVE FOR PNEUMATIC MUSICAL INSTRUMENTS. EUGENE DE KLEINST, Tonawanda, N. Y. Filed Nov. 27, 1905. Serial No. 289,208.

844,936. PNEUMATIC WATER-LIFT. WILLIAM A. HARRIS and BENJAMIN S. H. HARRIS, Grfeenville, S. C., assignors of four-sixteenths to J. C. Fitzgerald and one-fourth to J. P. Carlisle, Greenville, S. C. Filed June 15, 1906. Serial No. 321,886.



Claim.—The combination substantially as herein described of a supply-tank, a reservoir-tank, a purifier or filter tank, a pipe extending from the supply-tank to the reservoir-tank and having a discharge-faucet, a check-valve between the discharge-faucet and the supply-tank and opening toward the supply-faucet, and a stop-cock between the faucet and the reservoir-tank, a branch pipe leading from the connecting-pipe to the purifier or filter tank and supplied in advance of said filter-tank with an emergency-valve, a coupling and a plug connected with said branch pipe, an air-pipe leading from the filter-tank through the said coupling to the supply-tank and having an intermediate valve, an exhaust-pipe leading from the purifier-tank above the water-level thereof and having a faucet.

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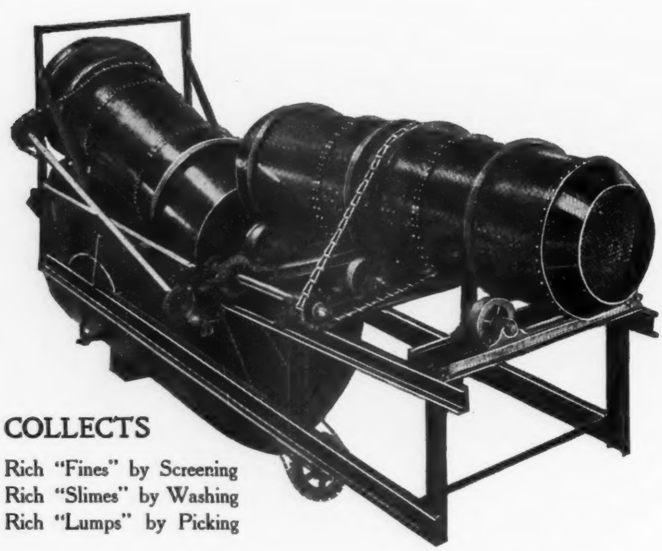

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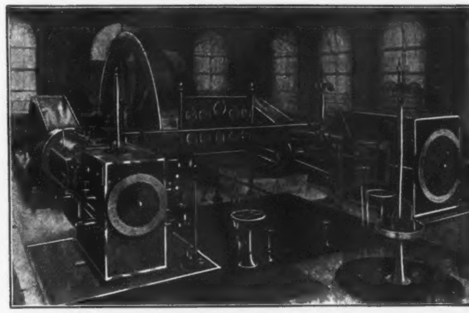
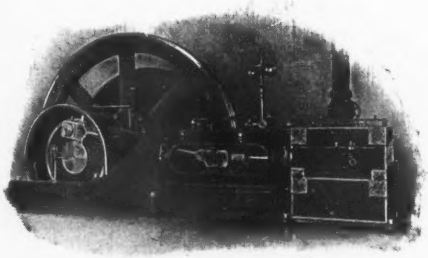




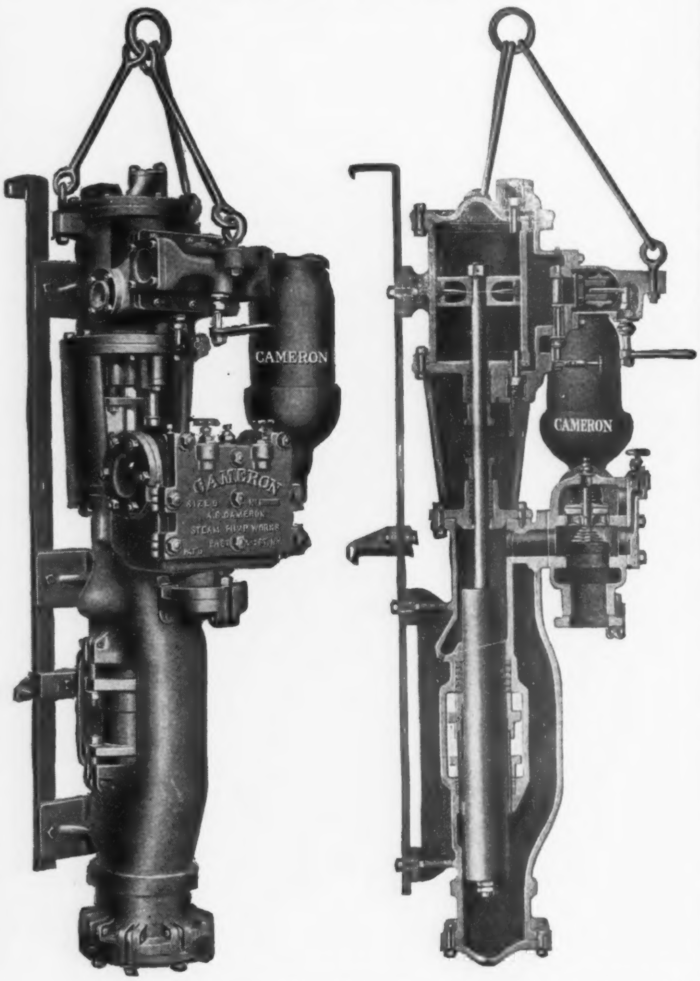
INDEX TO ADVERTISERS.

THE SLOGAN OF THE CAMERON—"CHARACTER: THE GRANDEST THING."

CAMERON PUMPS

Are economical in the best sense.
Cost of Maintehance.

JUST AS EFFICIENT WITH COMPRESSED AIR AS WITH STEAM.



Unsolicited Testimonials Versus Fairy Tales.

Lackawanna Iron & Steel Company,
Wehrum, Pennsylvania'
A. S. Cameron Steam Pump Works,
New York, N. Y.

Gentlemen :—We now have seven of your pumps in use, two of which are your 14 x 8 x 18 Regular Horizontal Plunger Pumps, outside packed. We are required to handle from 1,200 to 1,500 gallons a minute from the faces of each slope while sinking. All of the other pumps in use have two to four times the rated capacity of yours, yet your pumps are regularly, day and night, handling from one to one and one-half times as much water as any of the others, and doing it with less attention and care, and we place greater dependency on these than on any of the others.

Owing to an accident to a duplex pump, one of your pumps is now drowned out and has been for three weeks, and and it is still operating under 275 feet of water, running on compressed air, and handling double its rated capacity, and holding the water sufficiently in check to save two other pumps in the same slope pumping from higher levels. Is it any wonder that we have the highest regard for the "CAMERON" pump?

Yours very truly,
C. R. CLAGHORN, Supt.,
LACKAWANA IRON & STEEL CO.

Electric Light & Ice Company.
Harrison, Arkansas.
A. S. Cameron Steam Pump Works,
New York, N. Y.

Gentlemen :—Express us (Wells Fargo) two brass linings for water cylinder end of your Size 3 pump—these are Nos. 16049 and 20063.

Send us information as to removing old lining and installing new.

No. 16049 has operated 18 hours per day since 1895, and has cost us nothing for repairs until the present. No 20063 has been in 24 hours per day since 1900. Its water has been gritty with sand, however, and its water end is in worse shape than the older.

You are to be congratulated on this most excellent record. Working side by side with the old pump, was a condenser feed pump, new duplex——followed by a ——, followed by a————; all of these are now in the scrap pile and the old pump as good as new when the water cylinder is renewed,

Yours very truly,
R. M. FELLOWS, Mgr.,
ELECTRIC LIGHT & ICE CO.

These are the outside and sectional views of a Cameron Vertical Plunger Sinking Pump. Look at the construction.

We Build Pumps For Every Service.

To get a better idea of Cameron characteristics—read what users say as well as our Catalogue Edition "G," which will be sent to you on request.

A. S. CAMERON STEAM PUMP WORKS,

FOOT OF EAST 23D STREET

NEW YORK.

Mar. 1907

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